

# Two-fluid simulations of solar partially ionized atmosphere

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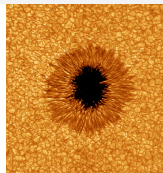
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# Sun atmosphere layers

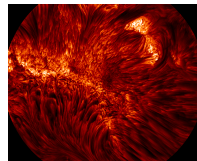
## Photosphere

- collisions dominated: LTE, MHD
- relatively easy observations
- diagnostics techniques well developed



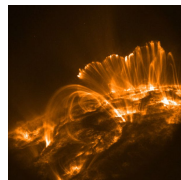
## Chromosphere

- not fully collisionally coupled: NLTE, No MHD (frequently not taken into account)
- very few spectral lines
- complicated radiative diagnostics



## Corona

- magnetically dominated
- very low density
- all ionized, MHD can be applied

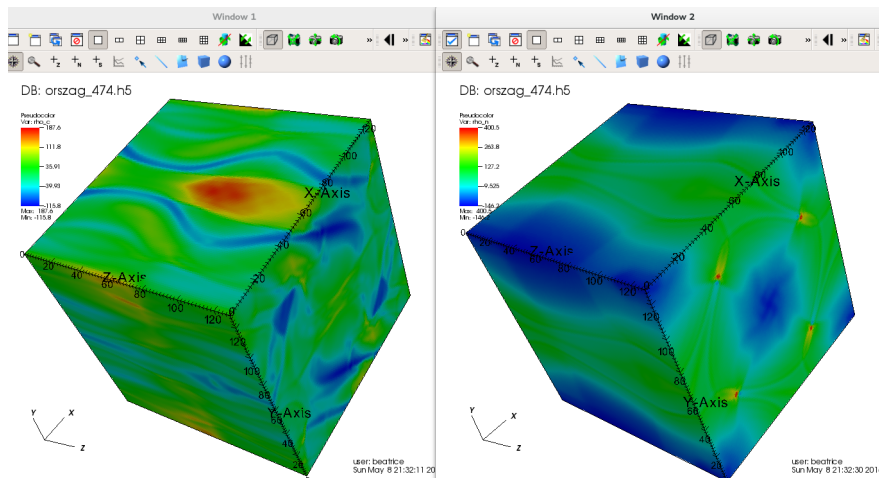


# Plasma models

- system of first order non linear partial differential equations which must be integrated in time
- Approximations:
  - MHD-1fluid: all the particles are considered as a whole.  
Assumption: strongly collisional plasma. A system of 8 unknown variables  $(p, \rho, v_x, v_y, v_z, B_x, B_y, B_z)$
  - 2-fluid: Neutral particles do not feel electromagnetic forces and may move differently from charged particles so collision rates between charged particles and neutral particles may not be the same like inside one specie. We consider the fluid variables  $(p, \rho, v_x, v_y, v_z)$  different for charged and neutral particles. A system of 13 unknown variables.
  - furthermore we could split the charges into ions and electrons as sometimes forces act differently on them or even consider each specie of ions in order to gain more resolution over the process

- including 2 fluid equations into Mancha code
  - fortran 90
  - parallelization with MPI
  - output in hdf5
- making 2-fluid simulation
  - generation of initial conditions (python)
  - executing the code
  - visualization and analysis (visit or python)

# Test result in visit



**Figure 1:** density of charges and neutrals in Orszag test after 474 iterations where they evolve independently (collision terms between neutrals and charges are set to 0)